

Diurnal Differences in OLR Climatologies and Anomaly Time Series



Joel Susskind, Jae N. Lee, Lena Iredell, and Norm Loeb

NASA GSFC Sounder Research Team (SRT)

CERES Science Team Meeting, LaRC, VA, May 6, 2015



- Introduction
- AIRS and CERES OLR comparison
 1. Climatologies
(OLR, clear sky OLR, LW cloud radiative forcing)
 2. Anomalies

AIRS Version-6 Level-3 Products Used

- ✧ OLR and OLRclr are computed by the OLR Radiative Transfer Algorithm (*Iacono et al.*, 2008) for 16 spectral bands with the AIRS retrieved geophysical parameters (*i.e.*, T_s , $T(p)$, $O_3(p)$, $CO_2(p)$, $H_2O(p)$, *cloud height*, and *cloud fraction*) for a given scene.
- ✧ Derived independently from CERES, OLR and spectral OLR are available.
- ✧ Diurnal difference is achieved by the difference from ascending (1:30PM) and descending (1:30AM) orbit.
- ✧ Cloud spectral emissivity is assumed to be gray in the OLR calculation, this is not true for cirrus clouds.

CERES EBAF Edition 2.8 Products Used

- ☞ OLR is primarily a measured quantity using broad banded observation taken at a single zenith angle.
- ☞ TOA OLR is balanced and filled to adjust SW and LW TOA fluxes to reduce the imbalance in the net flux.
- ☞ EBAF Edition 2.8 uses only Terra CERES

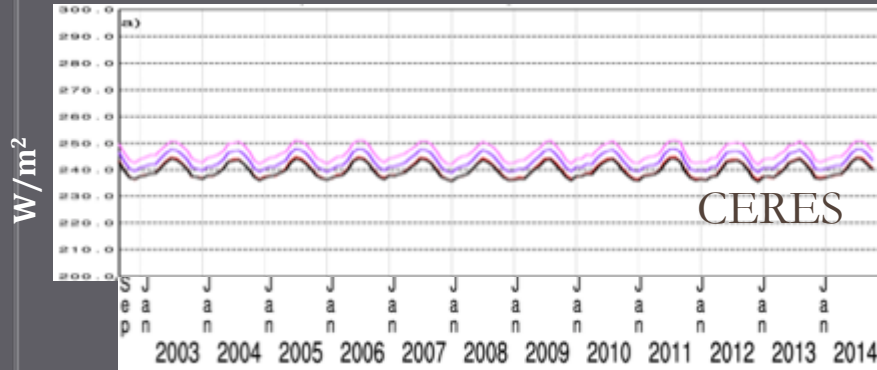
Part 1

Comparison of AIRS and CERES OLR Time Series and Climatologies

- ❧ CERES and AIRS climatologies are based on the same 12 consecutive years as AIRS (September 2002 through October 2014)
- ❧ For AIRS, 1:30 PM and 1:30 AM level-3 monthly mean, $1^{\circ} \times 1^{\circ}$ gridded OLR and clear sky OLR (OLRclr) products are analyzed separately from each other.
- ❧ Daily averaged values are calculated as a mean of two local time observations.

Area Mean OLR Time Series (W/m^2)

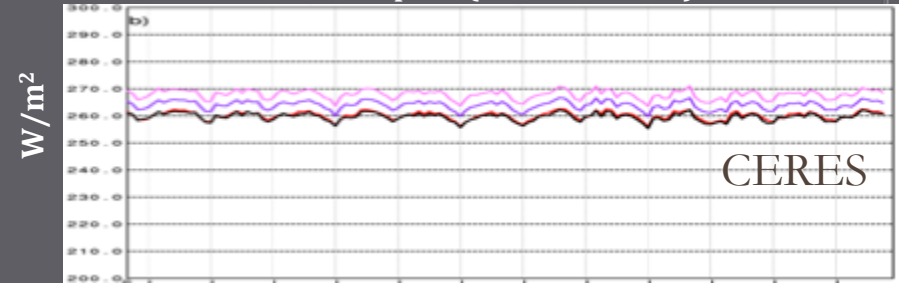
September 2002 through October 2014
Global



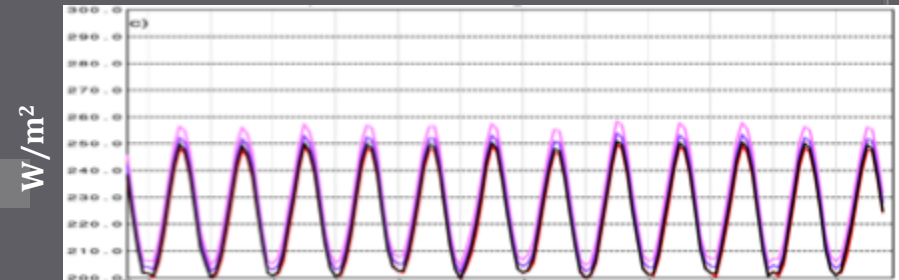
AIRS 1:30 PM AIRS 1:30 AM AIRS AM/PM Average CERES

- CERES global mean OLR closely matches AIRS 1:30AM values.
- OLR is time of day dependent.
- Global mean OLR is $7\text{W}/\text{m}^2$ higher at 1:30PM than 1:30 AM.

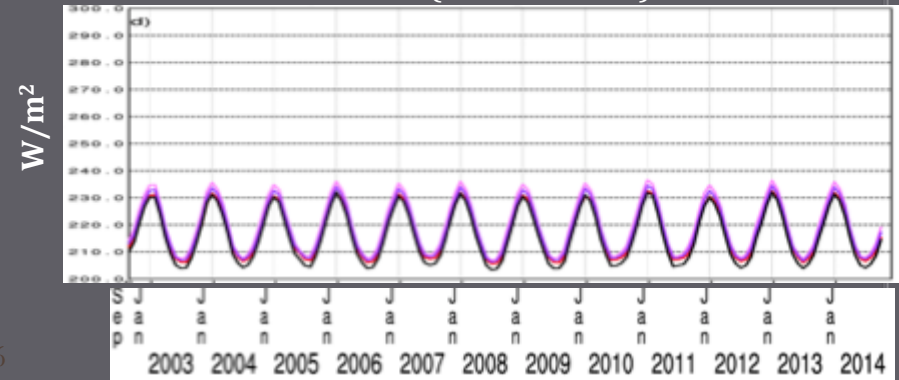
Tropics (30°N to 30°S)



NH (30°N to 90°N)

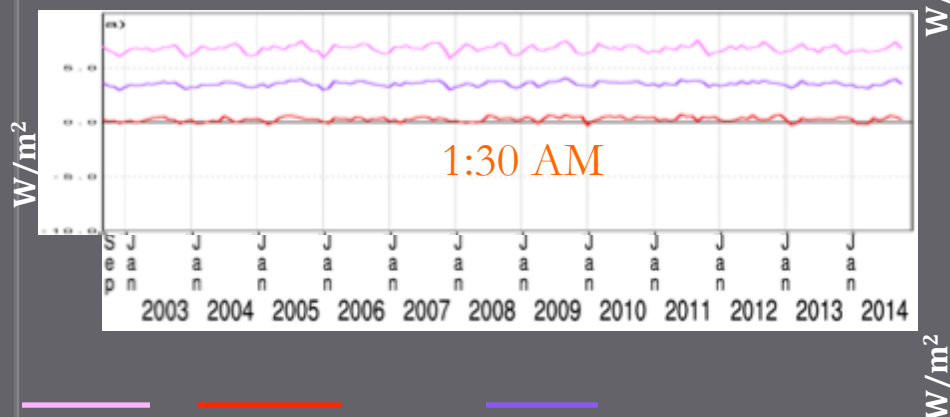


SH (30°S to 90°S)



Differences in Area Mean OLR Time Series (W/m^2)

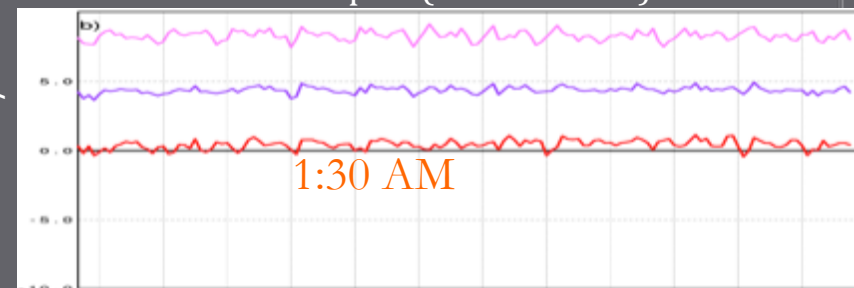
September 2002 through October 2014
Global



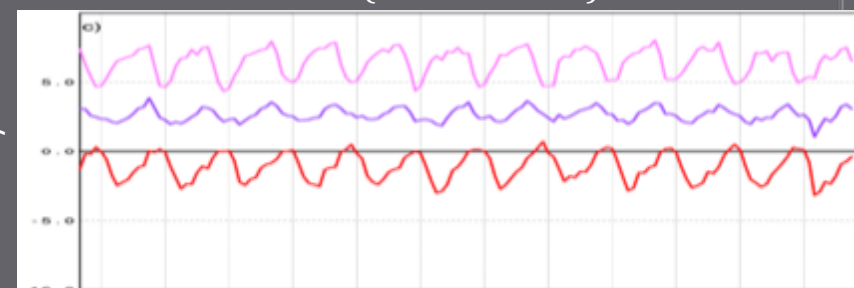
AIRS 1:30 PM AIRS 1:30 AM AIRS AM/PM Average

- AIRS/CERES OLR global and tropical mean differences are roughly constant over the 12 yrs.
- CERES global mean OLR closely matches AIRS 1:30AM values, it is also true in the tropics, and extra tropics during summer.
- In NH, difference with 1:30AM and 1:30PM is out phase.

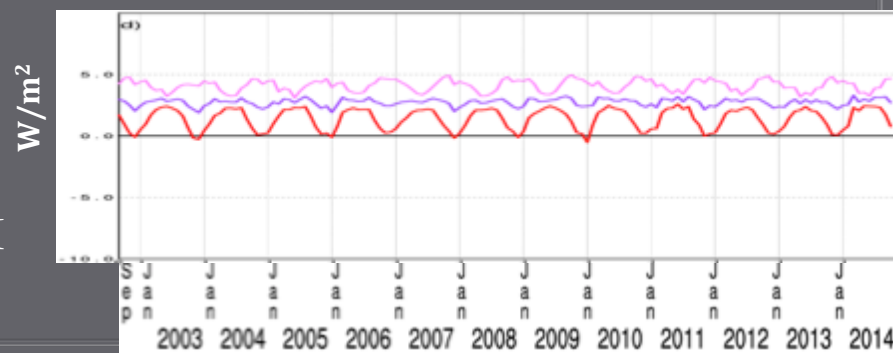
Tropics (30°N to 30°S)



NH (30°N to 90°N)



SH (30°S to 90°S)



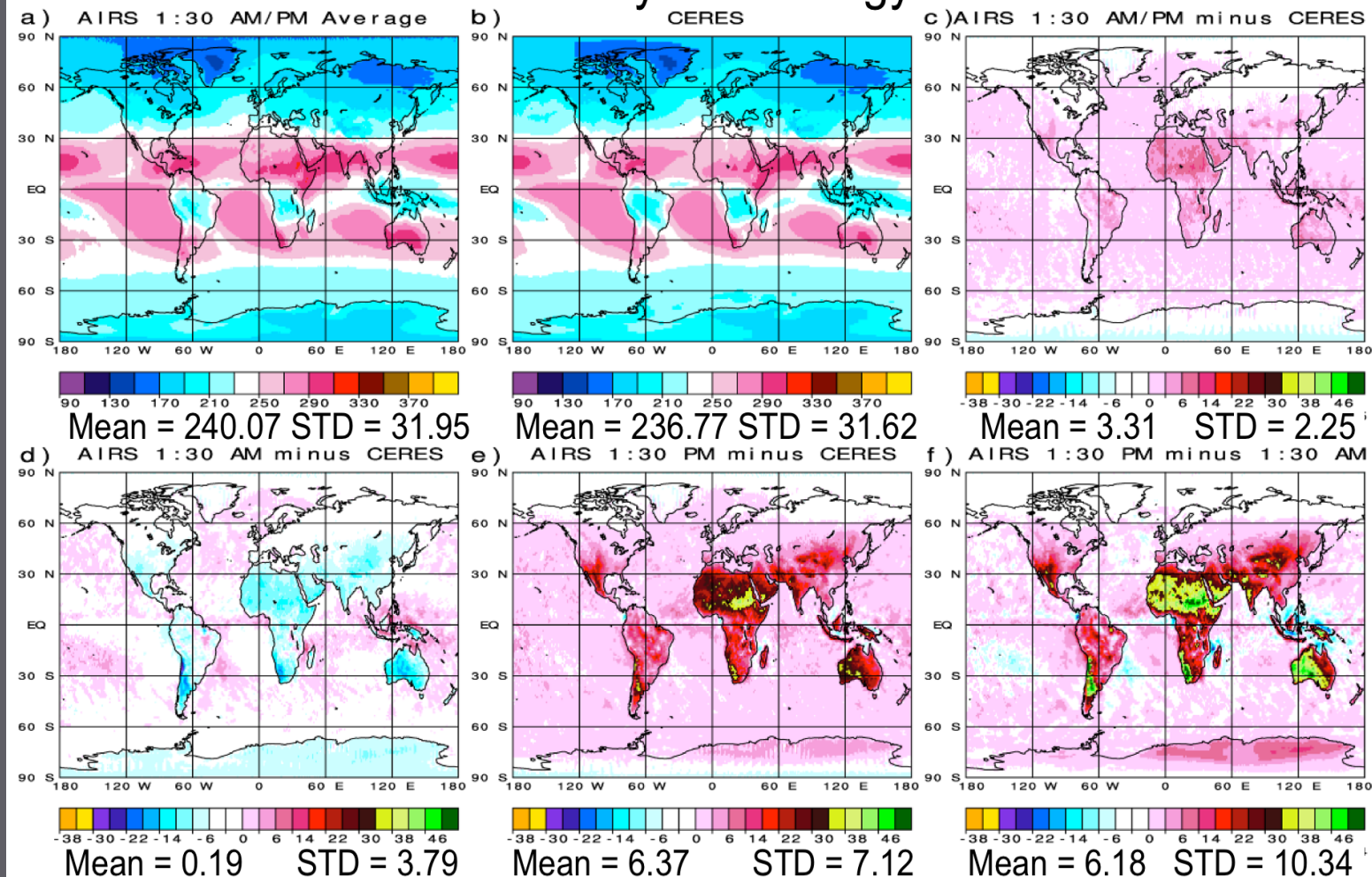
In SH, AIRS OLR is higher in every case.



Differences Between AIRS and CERES OLR Time Series (W/m^2)

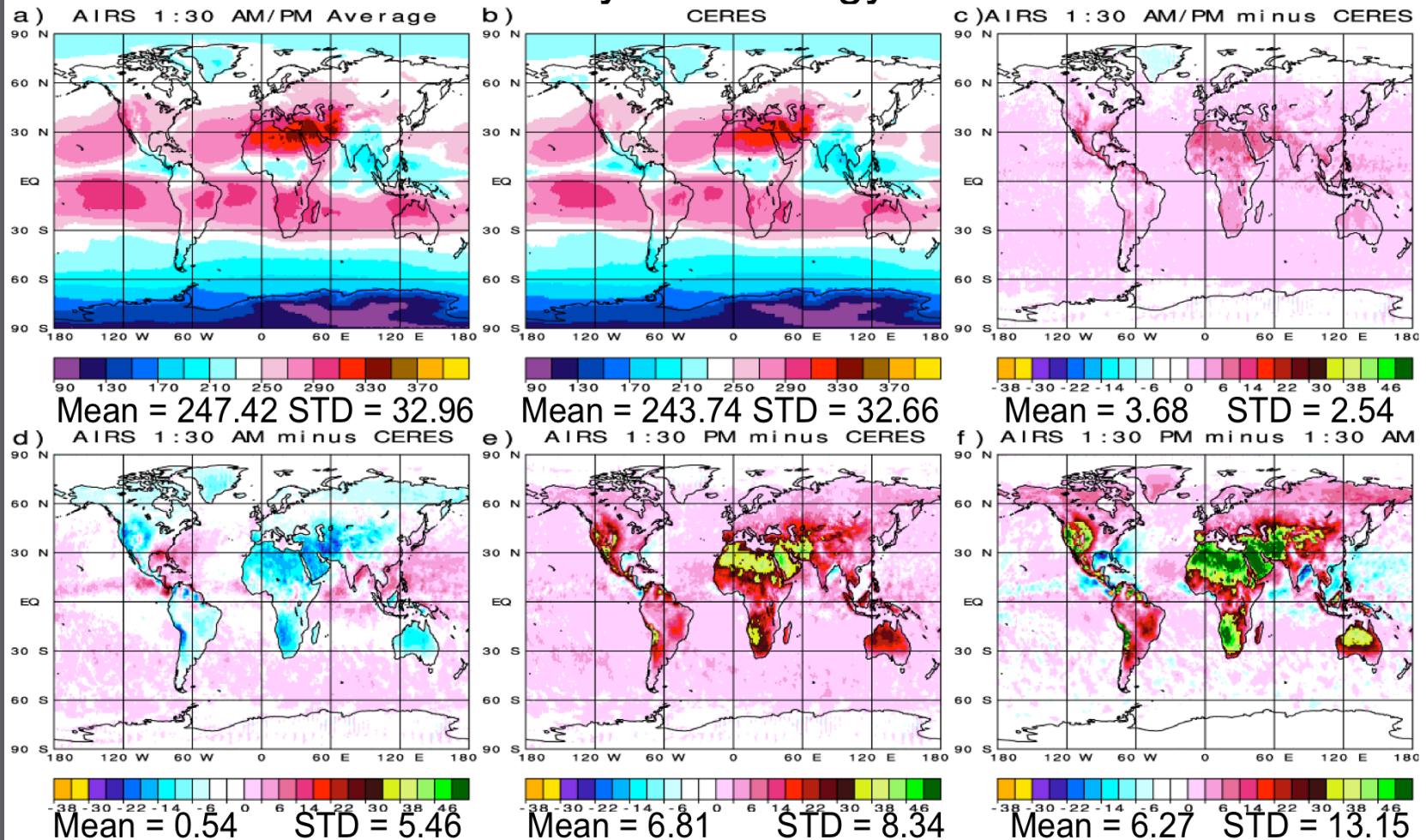
	AIRS 1:30AM minus CERES	AIRS 1:30PM minus CERES	AIRS 1:30PM/AM minus CERES
Global Mean			
Bias	0.29	6.77	3.53
STD	0.24	0.33	0.22
Slope ($\text{W}/\text{m}^2/\text{yr}$)	0.0133 ± 0.0111	0.0042 ± 0.0160	0.0086 ± 0.0103
Tropical Mean			
Bias	0.44	8.23	4.35
STD	0.35	0.34	0.24
Slope ($\text{W}/\text{m}^2/\text{yr}$)	0.0256 ± 0.0157	0.0012 ± 0.0166	0.0132 ± 0.0106
30N-90N Mean			
Bias	-1.13	6.63	2.75
STD	0.98	1.00	0.46
Slope ($\text{W}/\text{m}^2/\text{yr}$)	-0.0182 ± 0.0475	0.0146 ± 0.0487	-0.0020 ± 0.0222
30S-90S Mean			
Bias	1.37	4.08	2.73
STD	0.85	0.48	0.30
Slope ($\text{W}/\text{m}^2/\text{yr}$)	0.0204 ± 0.0411	-0.0003 ± 0.0277	0.0100 ± 0.0140

Outgoing Longwave Radiation (W/m^2) January Climatology



- While AIRS 1:30AM global mean OLR matches CERES, ocean area are higher and land areas are lower in AIRS.
- AIRS daily averaged OLR is higher compared to CERES every where, but the biases reflect AIRS day/night difference pattern.

Outgoing Longwave Radiation (W/m^2) July Climatology



- Results in July are similar to those in January.
- Diurnal differences in AIRS show deep convective cloud region over ocean, and diurnal heating over land.

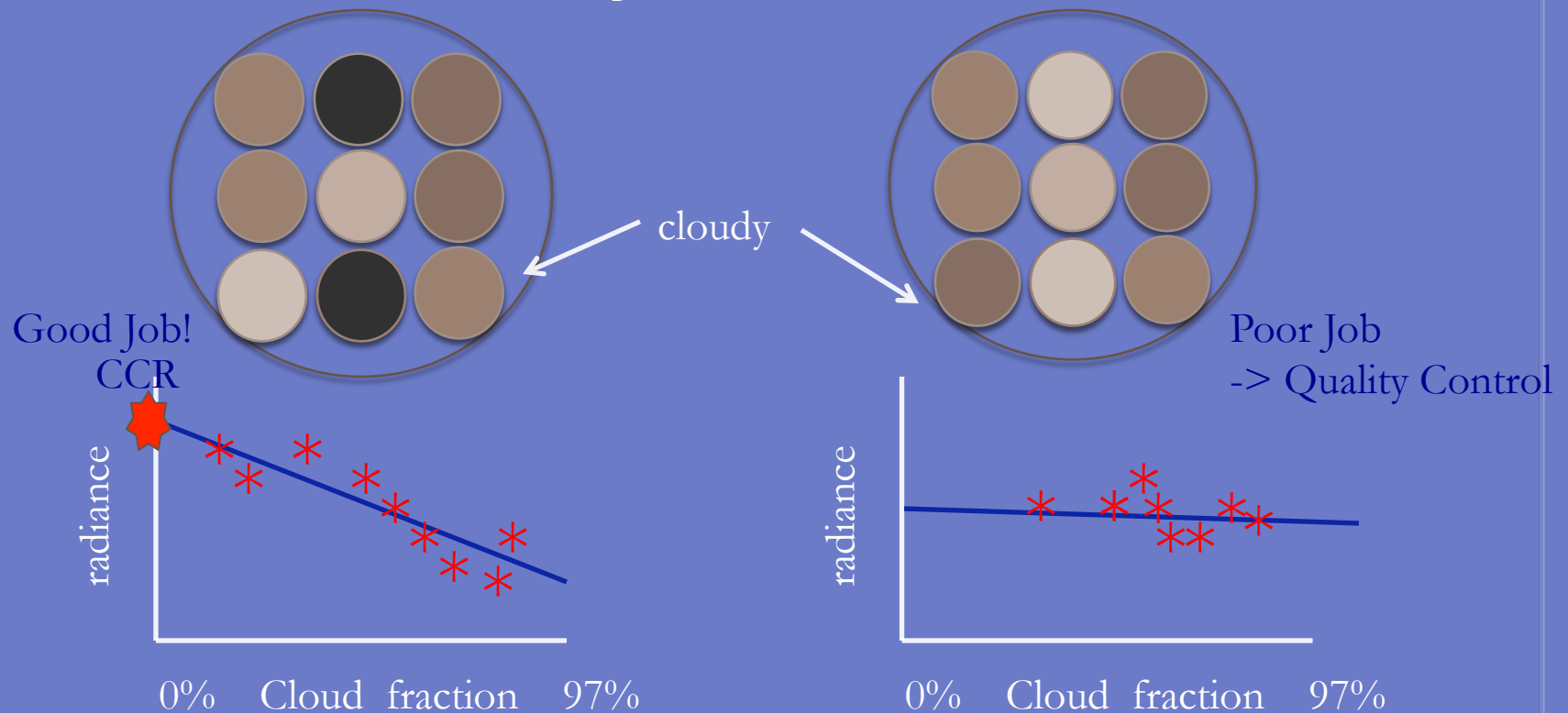
Clear Sky OLR (OLRclr)

- ❧ One might expect differences between AIRS and CERES OLRclr to be large, as a result of even more different sampling and methodology with respect to generating L3 OLRclr product.
- ❧ CERES determines OLRclr for all FOVs thought to be cloud free, and fills appropriate values for those not cloud free FOVs.
- ❧ Unlike CERES, AIRS OLRclr does not require the scene to be clear because OLRclr is a computed parameter, which represents the longwave flux emanating from the clear portion of the AIRS scene as observed under partial cloud cover conditions. 80% of all FOV's observed by AIRS are included in the L2 OLR products used to generate the L3 OLRclr product.
- ❧ From the grid point spatial coverage perspective, ~96% of those grid points covering the AIRS OLR products contain OLRclr product.

AIRS cloud clearing

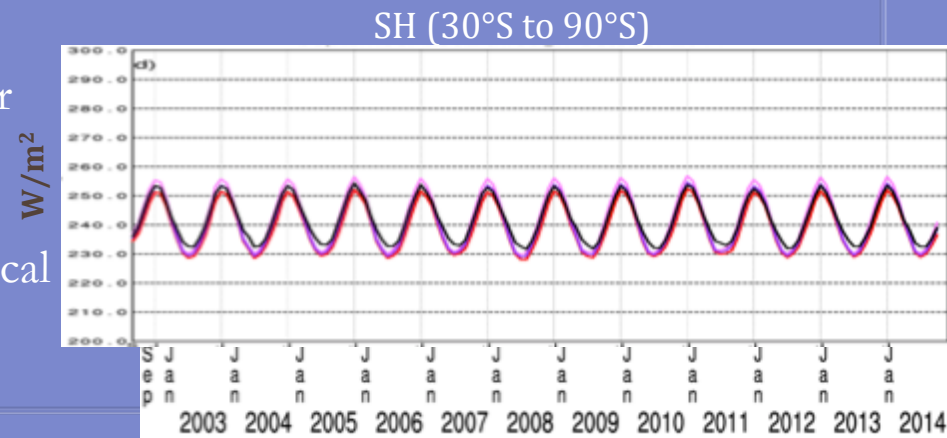
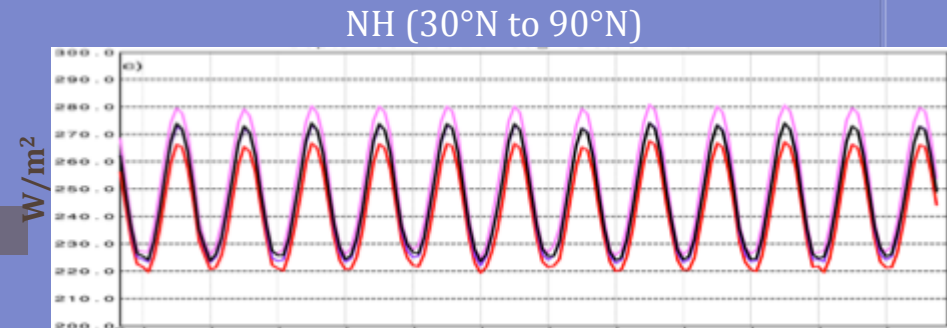
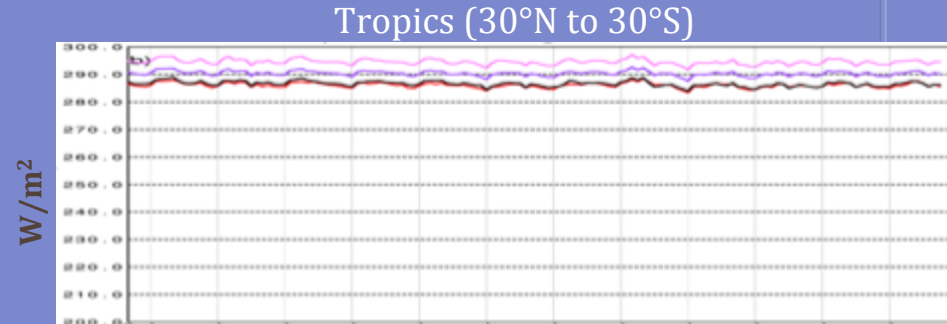
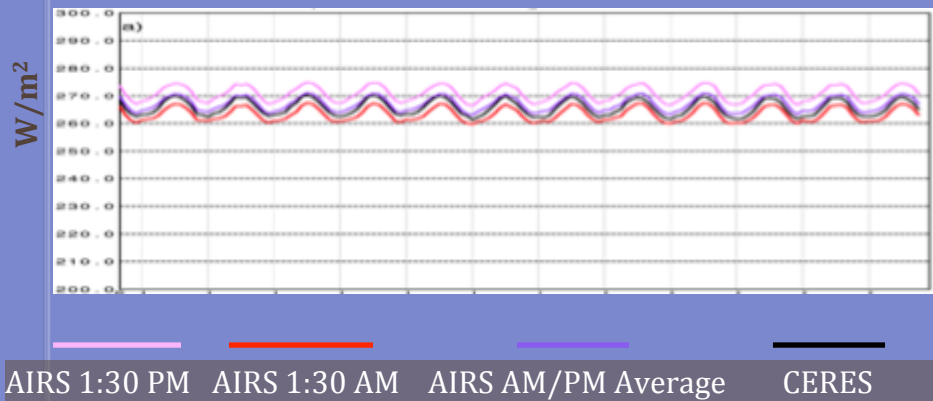
- Assumes that other conditions are *homogeneous* within 9 footprints except **cloud conditions**.
- From the radiances of 9 footprints, cloud cleared radiance can be determined by linear extrapolation.
- This method performs well under most cloud cases but fails with cloudiest cases.

Example for one channel



Area Mean OLRclr Time Series (W/m^2)

September 2002 through October 2014
Global

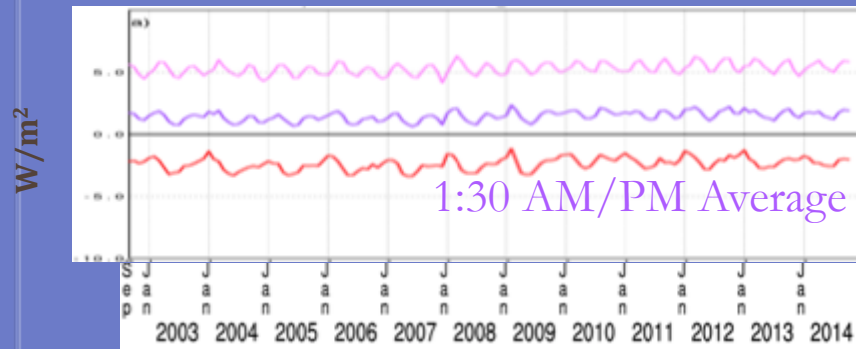


- OLRclr is higher than all sky OLR.
- Global mean AIRS OLRclr is $7.5W/m^2$ higher at 1:30PM than 1:30 AM.
- CERES global mean OLR closely matches AIRS 1:30AM/PM average values, while tropical mean matches with AIRS 1:30AM values.



Differences in Area Mean OLRclr Time Series (W/m^2)

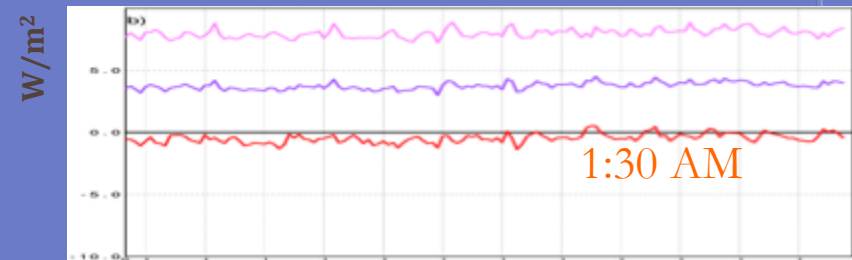
September 2002 through October 2014
Global



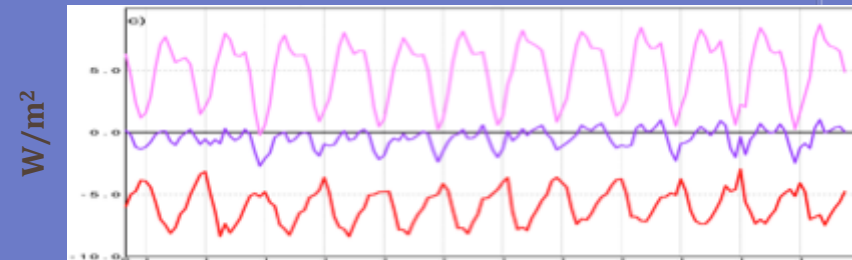
AIRS 1:30 PM AIRS 1:30 AM AIRS AM/PM Average

- CERES global mean OLR closely matches AIRS 1:30AM/PM average values, while the tropical mean matches with 1:30 AM values.
- In NH, the difference in AM orbit and PM orbit is out phase with seasonal variation.

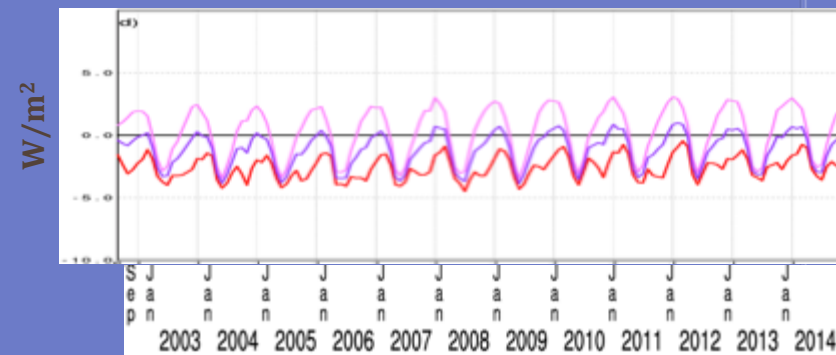
Tropics (30°N to 30°S)



NH (30°N to 90°N)

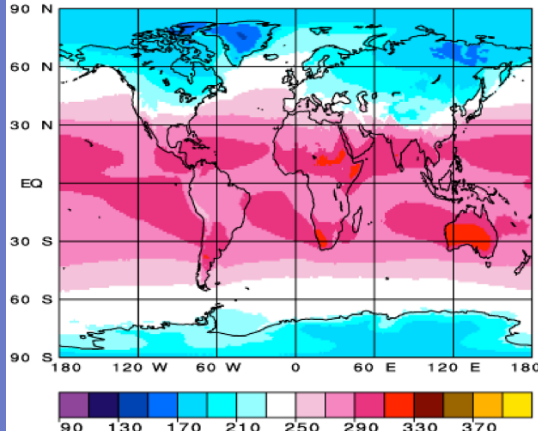


SH (30°S to 90°S)



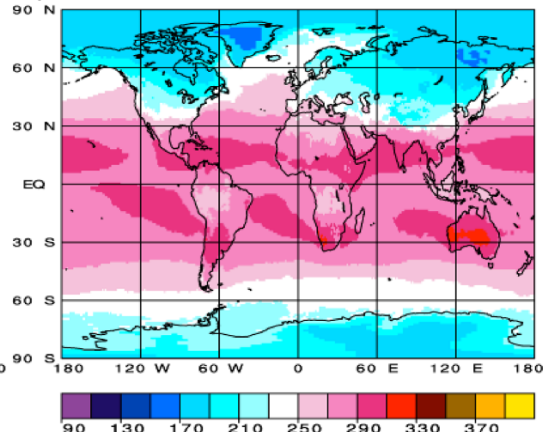
Clear Sky Outgoing Longwave Radiation (W/m^2) January Climatology

a) AIRS 1:30 AM/PM Average



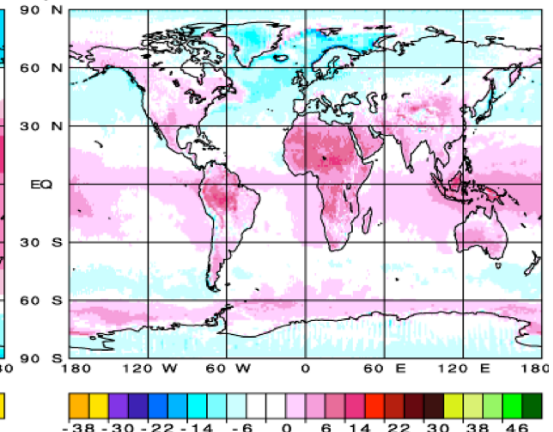
Mean = 264.08 STD = 30.16

b) CERES



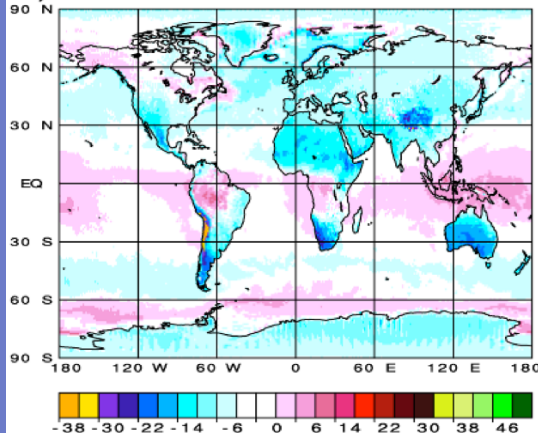
Mean = 262.41 STD = 28.89

c) AIRS 1:30 AM/PM minus CERES



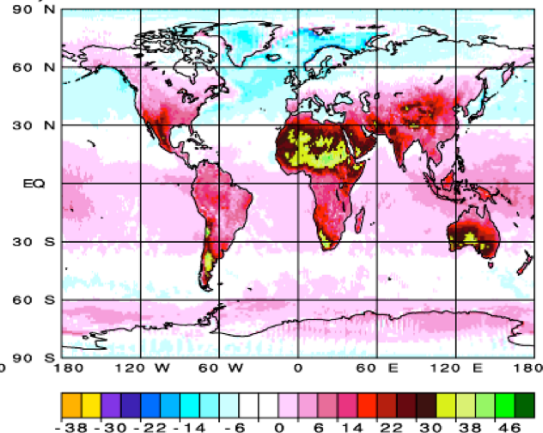
Mean = 1.66 STD = 4.07

d) AIRS 1:30 AM minus CERES



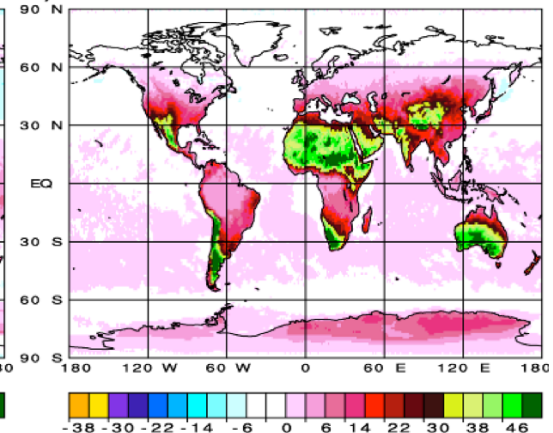
Mean = -1.68 STD = 5.48

e) AIRS 1:30 PM minus CERES



Mean = 5.01 STD = 8.69

f) AIRS 1:30 PM minus 1:30 AM

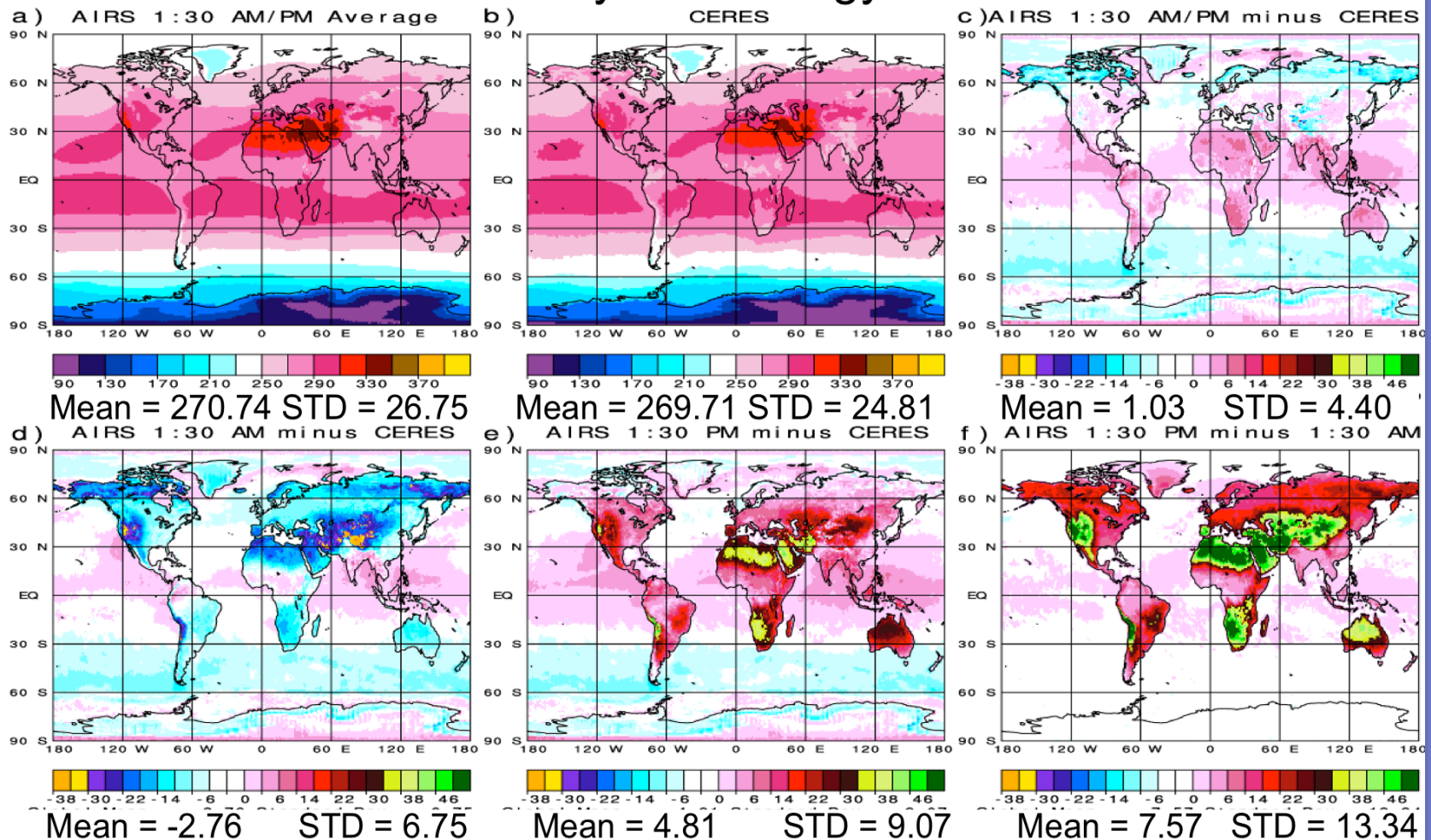


Mean = 6.69 STD = 12.03

15

- AIRS and CERES OLRclr climatology match better than might be expected, but unlike OLR, the biases are region dependent.

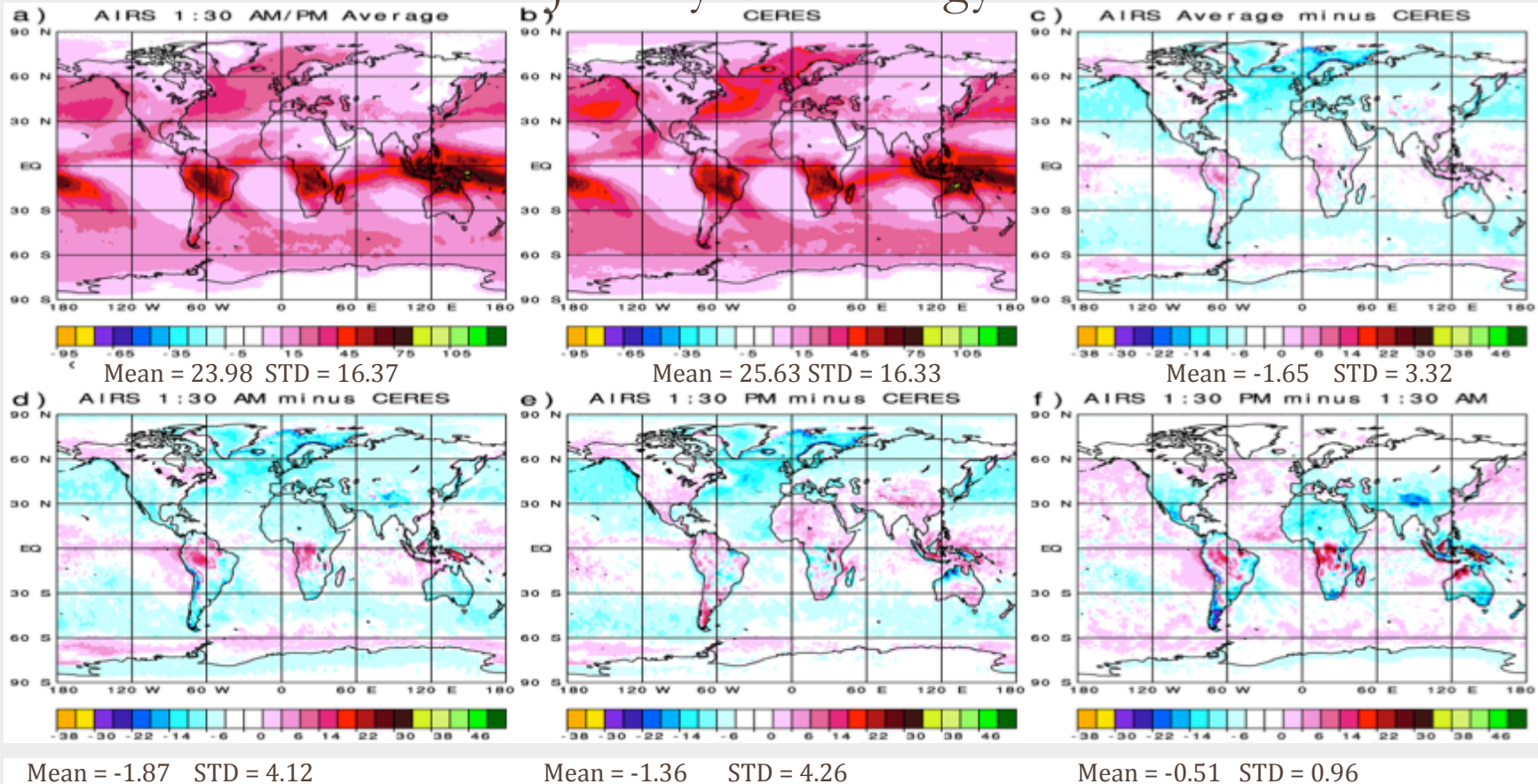
Clear Sky Outgoing Longwave Radiation (W/m^2) July Climatology



- Diurnal differences are larger over land during summer, these cause the contrast in AM and PM difference patterns.

Longwave Cloud Radiative Forcing (W/m^2)

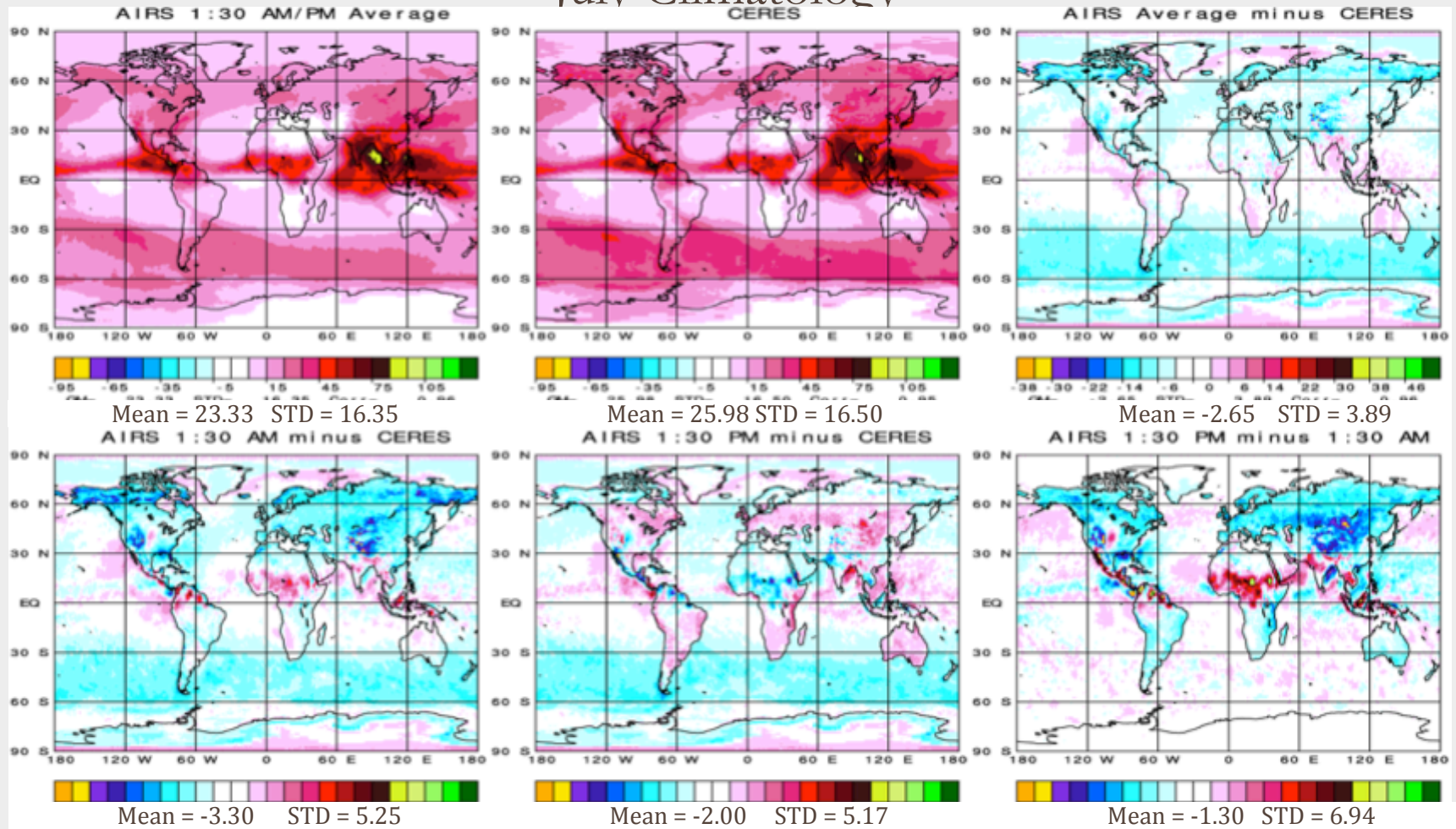
January Climatology



- The LWCRF is up to 75 W/m^2 over the tropics. The difference patterns are complex.
- AIRS values are lower throughout extra-tropical storm track regions polewards of 35 degrees, especially in the winter hemisphere.
- By the passage of cold front, it is cold and cloudy in general. AIRS sampling over those regions may cause low OLRclr values.

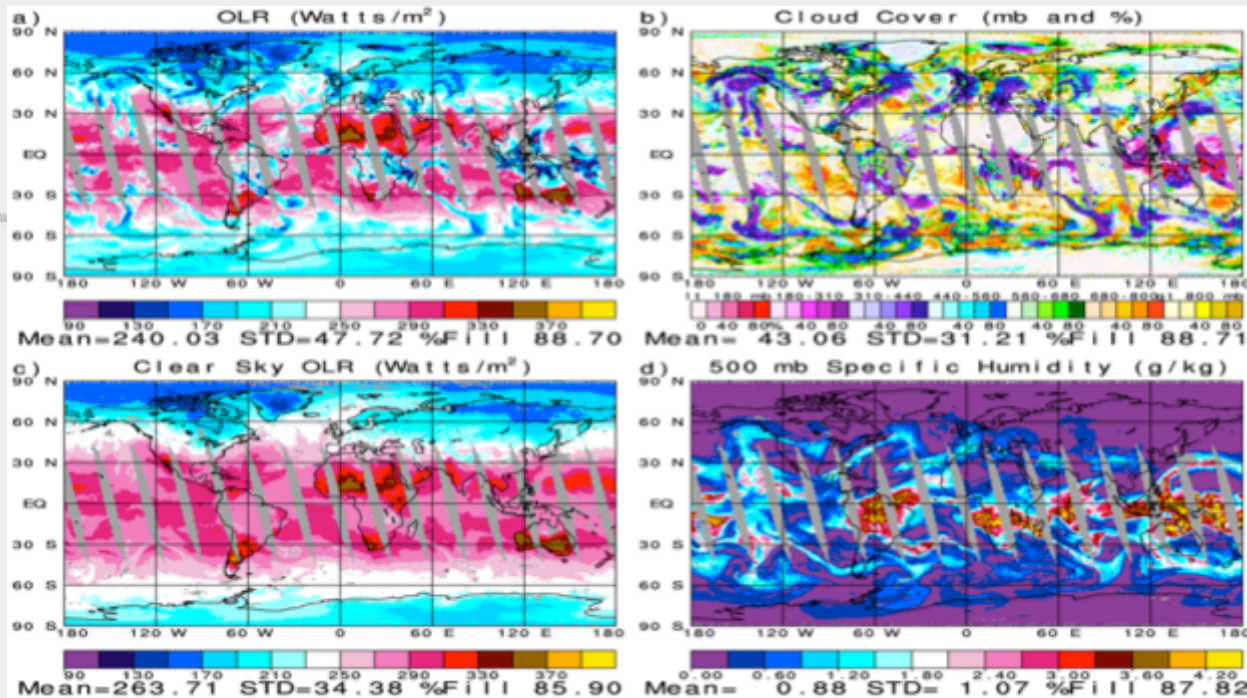
Longwave Cloud Radiative Forcing (W/m^2)

July Climatology



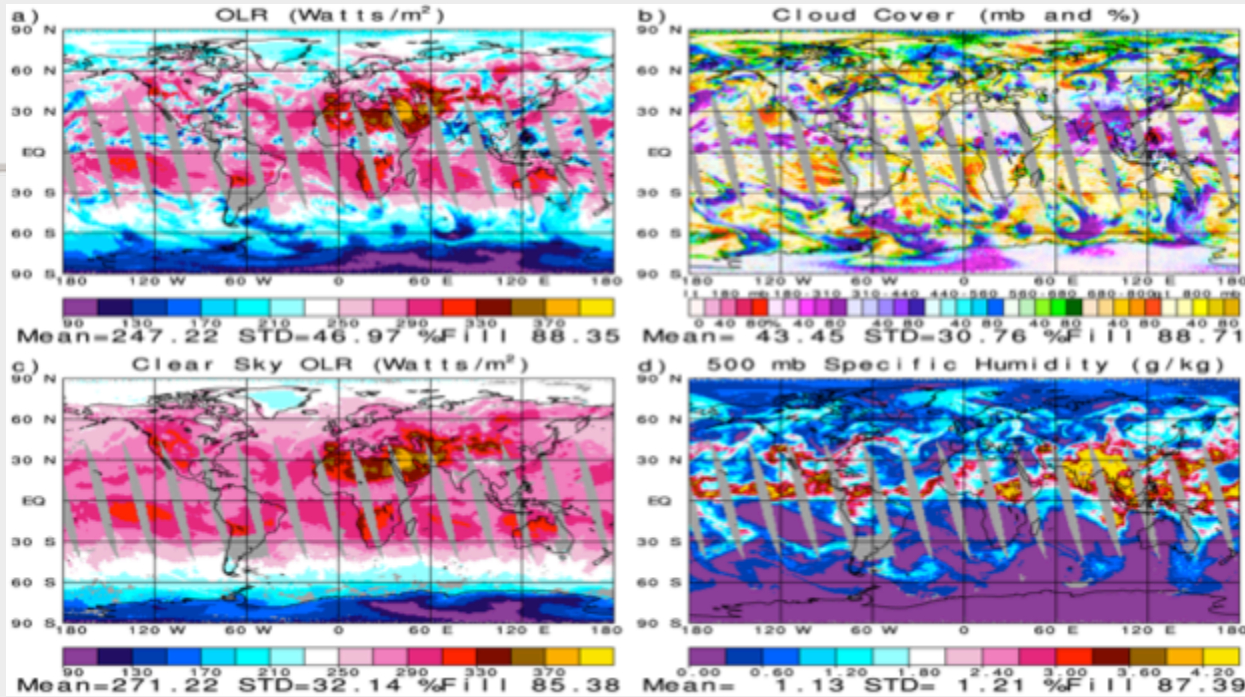
- The LWCRF is up to 100 W/m^2 over the tropics.
- AIRS values are lower throughout extra-tropical storm track regions in southern winter regions, polewards of 35S .

Daily fields : AIRS Version-6 January 15, 2014 1:30 PM



- ✧ About 89% of grids are covered in a single time period. About 96% of those grids were contained values for OLRclr.
- ✧ OLRs are low (high) where the surface skin temperature is low (high).
- ✧ OLRs are low where mid-high level clouds exist, where 500 mb specific humidity is also high.
- ✧ This lowers clear sky OLR in these regions as well.

Daily fields : AIRS Version-6 July 15, 2014 1:30 PM



- ✎ Correlation among OLR, surface skin temperature, clouds, and humidity are identical with NH winter, but the cloud pattern is different in two seasons.

Part 2

Comparison of AIRS and CERES OLR in Anomalies

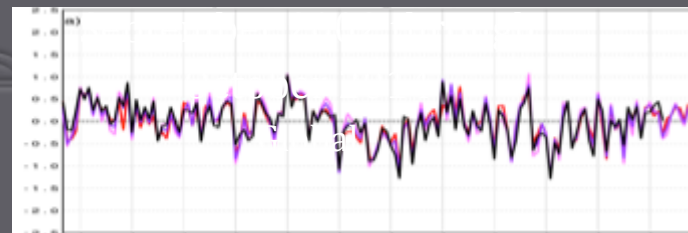
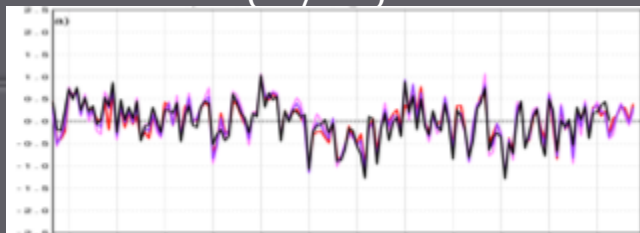
- CERES climatologies are based on the same 12 consecutive years as AIRS
 - Agreement in two data sets are valuable to assess the near term trend and inter annual variabilities in OLR and LWCRF.
-

AIRS and CERES OLR in Anomalies

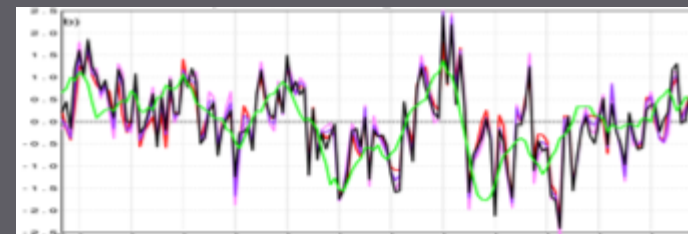
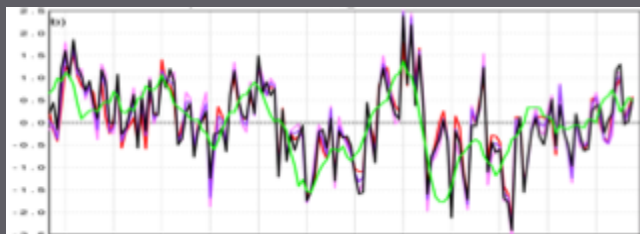
Area Mean OLR Anomaly
(W/m²)

Area Mean OLRclr Anomaly
(W/m²)

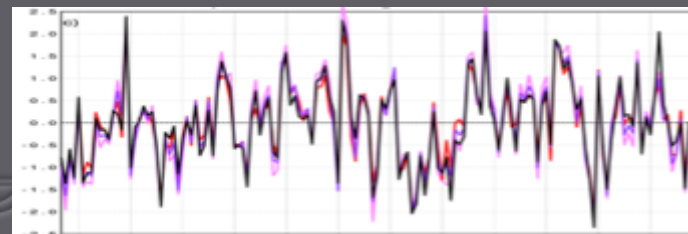
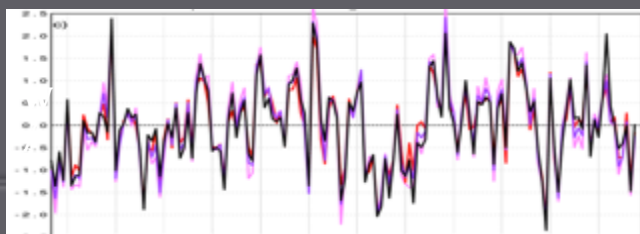
90°N to
90°S



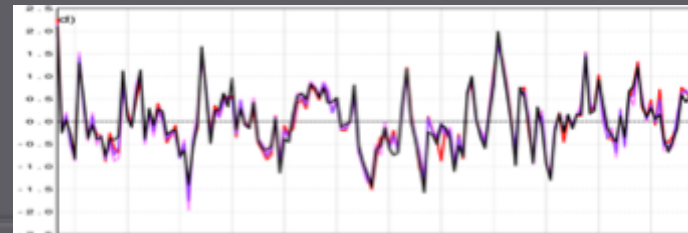
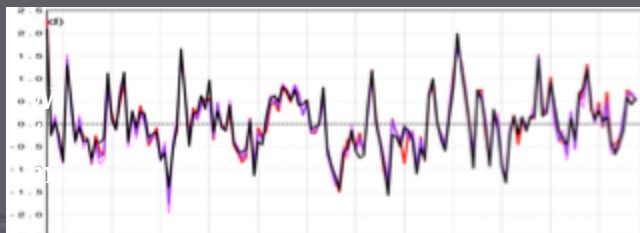
30°N to
30°S



30°N to
90°N



30°S to
90°S



22

AIRS 1:30 PM AIRS 1:30 AM AIRS AM/PM Average

CERES

NOAA El Niño 4 Index



Summary

- ❧ AIRS Version-6 OLR matches CERES Edition-2.8 OLR very closely on a $1^\circ \times 1^\circ$ latitude x longitude scale, both with regard to absolute values, and also with regard to anomalies of OLR. There is a bias of $\sim 3.5 \text{ W/m}^2$, which is nearly constant both in time and space.
- ❧ Contiguous areas contain large positive or negative OLR difference between AIRS and CERES are where the day-night difference of OLR is large.
- ❧ For AIRS, the larger the diurnal cycle, the more likely that sampling twice a day is inadequate.
- ❧ Lower values of OLR_{clr} and LWCRF in AIRS compared to CERES is at least in part a result of AIRS sampling over cold and cloudy cases.

Back ups



Comparison with MERRA 2

